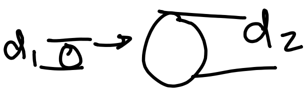
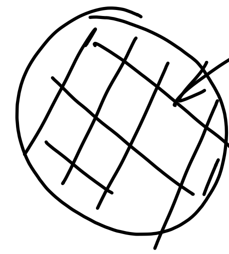
Common Transmission Media

Exercise 1: How much does a cable's resistance increase when the gauge size increases by 6? By 3? Hint: a wire's resistance is proportional to its cross-sectional area. inversely





$$A = \pi \left(\frac{d}{2}\right)^2 = \frac{\pi d_2^2}{4}$$

$$A = \pi r^2 \qquad r = \frac{d}{2}$$

$A_1 \quad d_1$

$A_2 \quad d_2 \quad d_2 = 2d_1$

$$\frac{A_2}{A_1} = \frac{\pi/4}{\pi/4}\frac{(2d_1)^2}{d_1^2} = 4 \qquad A_2 = 4A_1 \qquad A_1 = \frac{A_2}{4}$$

$$\frac{R_2}{R_1} = \frac{1/A_2}{1/A_1} = \frac{A_1}{A_2} = \frac{\frac{A_2}{4}}{A_2} = \frac{1}{4} \qquad R_2 = \frac{R_1}{4}$$

if increase gauge by 6 resistance is $\frac{1}{4}$ of previous.

$$d \approx 0.25 \times 2^{-\frac{(n-24)}{6}} = 8 \times 2^{-\frac{n}{6}} \text{ mm}$$

$$d_1 = 8 \cdot 2^{-\frac{n_1}{6}} \qquad d_2 = 8 \cdot 2^{-\frac{n_2}{6}}$$

$$n_2 = n_1 + 3$$

$$\frac{d_2}{d_1} = \frac{8 \cdot 2^{-n_1/6}}{8 \cdot 2^{-n_2/6}} = \frac{2^{-n_1/6}}{2^{-(n_1+3)/6}} = \frac{2^{-n_1/6}}{2^{-n_1/6} \cdot 2^{-3/6}}$$

$$= 2^{3/6} = 2^{1/2} = \sqrt{2}$$

$$\frac{A_2}{A_1} = \frac{d_2^2}{d_1^2} = \frac{(\sqrt{2}\, d_1)^2}{d_1^2} = 2$$

$$\frac{R_2}{R_1} = \frac{A_1}{A_2} = \frac{A_2}{2A_1} = \frac{1}{2}$$

∴ if gauge increase by 3 resisistance drops by 2.

Exercise 2: What is the characteristic impedance of a lossless cable with an inductance of 94 nH per foot and capacitance of 17pF/ft?

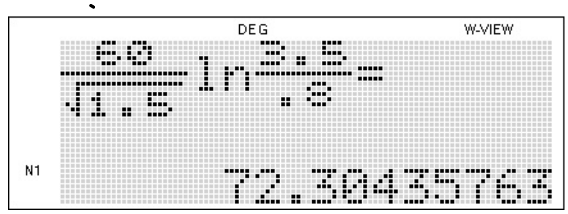
$L = 94\,nH/ft$

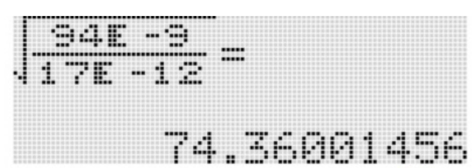
$Z_0 = ?$

$C = 17\,pF/ft$

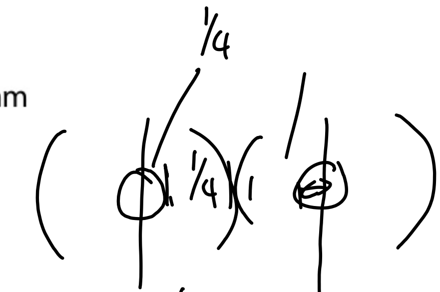
$$Z_0 = \sqrt{\frac{L}{C}}$$

Ω





Exercise 3: What is the characteristic impedance of UTP made from 24-gauge wire with polyethylene insulation ($\varepsilon_r = 2.2$) of 0.25mm thickness?



$S = 4 \times \frac{1}{4} = 1\,mm$

$D = 24\ gauge = 0.5\,mm$

$$Z_0 = \frac{120}{\sqrt{\varepsilon_r}} \ln\left(\frac{2S}{D}\right)$$

$$= \frac{120}{\sqrt{2.2}} \ln\left(\frac{2.1}{0.5}\right) = \frac{120}{\sqrt{2.2}} \ln(4)$$

Ω

0.5 ← error in lecture notes

$$d \approx 0.25 \times 2^{-\frac{(n-24)}{6}} = 8 \times 2^{-\frac{n}{6}}\ \text{mm}$$

for $n = 24$ $D = 0.25 \times 2^{-\frac{(24-24)}{6}} = 0.25 \cdot 2^{-0}$??

$= 0.25\,mm$

$D = 8 \times 2^{-\frac{24}{6}} = 8 \times 2^{-4} = \frac{8}{16} = 0.5\,mm$

Exercise 4: What is the characteristic impedance of a co-ax cable with a 0.8mm diameter center conductor, 3.5mm diameter shield and foamed polyethylene between them that has a dielectric constant of 1.5?

$d = 0.8$

$D = 3.5$

$\varepsilon_r = 1.5$

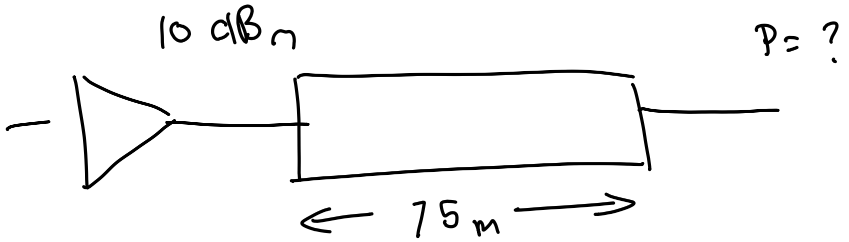
$$Z_0 = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{D}{d}\right) =$$

$$= \frac{60}{\sqrt{1.5}} \ln\left(\frac{3.5}{0.8}\right)$$

$$= \frac{60}{\sqrt{1.5}} \ln\frac{3.5}{0.8} = 72.30435763 \ \Omega$$

$Z_0 = 75\ \Omega$

Exercise 5: An 800 MHz signal is output from a CATV amplifier at a power level of 10dBm. What power level would you expect at the other end of a 75m run of co-ax whose loss is specified as 24dB/100m at 800 MHz? Hint: gain $G_{dB} = 10\log_{10}(P_{out}/P_{in})$.



$10\,mW \cdot \frac{1}{100} = 100\,\mu W$

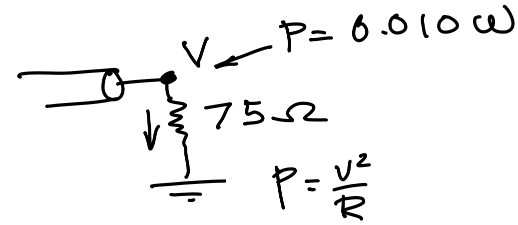
Loss is 24dB/100m

$$\text{Loss} = 24\,dB \cdot \frac{75}{100}\frac{m}{m} = 24 \times \frac{3}{4} = 18\ dB.$$

Gain = −18 dB

$$P_{output} = P_{in} + \text{Gain} = 10\,dBm + -18\,dB = -8\ dBm$$

$P_{in} - \text{Loss}$



$P = \frac{V^2}{R}$

Exercise 6: Assuming the transmission line in the above example is properly terminated, what are the voltage and current at the input and output of the cable? Hint: $P = V^2/R$.

$Z_0 = \frac{V}{I} = 75\,\Omega$

$P_{in} = 10\ \text{dBm} = 10^{\frac{10}{10}} = 10\,\text{mW}$ $= 10\log_{10}(P)$

$P_{out} = -8\ \text{dBm} = 10^{\frac{-8}{10}} = 0.16\,\text{mW}$ $= 10^{\frac{P}{10}}$

$V = \sqrt{P \cdot R} = \sqrt{0.010 \cdot 75} = \sqrt{0.75} = 0.86\,V$

$I = \frac{V}{R} = \frac{0.86}{75} = 11.5\ \text{mA}$

Exercise 7: What is the velocity factor for a cable with polyethylene insulation ($\varepsilon_r = 2.2$)? How long would it take for a signal to propagate 100m? For a cable with air dielectric?

$v = \frac{d}{t}$

for $\varepsilon_r = 2.2$:

$VF = 0.67$

$t = \frac{d}{v} = \frac{100}{2\times10^8} = 0.5\times10^{-6}$

$v = c \cdot VF = 3\times10^8 \times 0.67 = 200\,\text{m}/\mu\text{s}$.

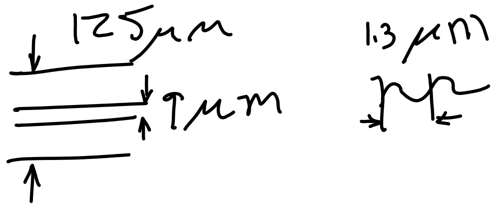
$= 2\times10^8\,\text{m/s}$.

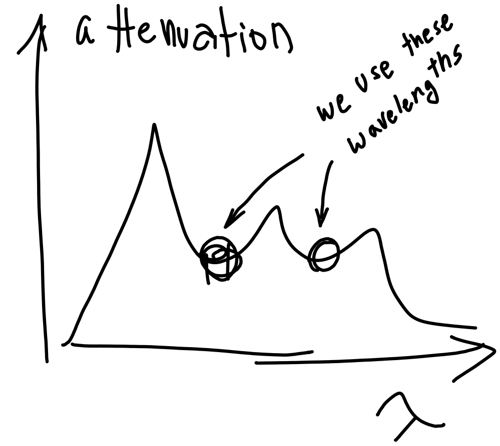
for $\varepsilon_r = 1$:

$VF = 1$

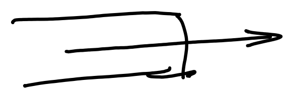
$t = \frac{100}{3\times10^8} = 0.33\,\mu\text{s}$.

Exercise 8: If the optical signal wavelength is 1330nm what is the frequency? Note that the wavelength is specified in free space, not in the fiber.





$$v = \frac{d(m)}{t(s)} = \frac{\lambda}{s} = \lambda f$$



$$f = \frac{v}{\lambda} = \frac{3\times10^{8}\ m/s}{1.33\times10^{-6}}$$

$$= 2.3\times10^{14}$$

$$233\times10^{12}$$

$$= 233\ THz$$

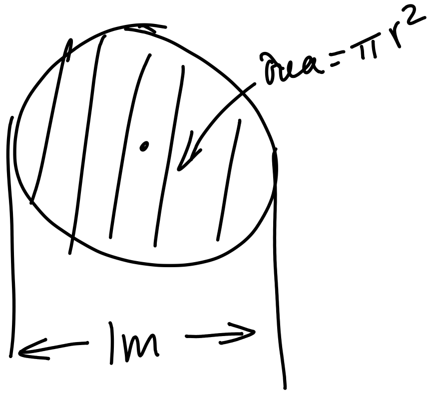
λ λ

f f

10^9 G

10^{12} T

Exercise 9: For some types of antennas, such as reflectors, the effective aperture is closely approximated by the physical area of the antenna. What are the approximate effective aperture and gain of a 1-m diameter Ku-band (≈ 15 GHz) satellite dish?



$$A_e \approx \text{Area} = \pi r^2 = \pi \left(\frac{d}{2}\right)^2$$

$$= \pi \left(\frac{1}{2}\right)^2 = \frac{\pi}{4} \approx \frac{3}{4}\ m^2$$

$\frac{\pi}{4}=$ 0.785398163

$$c = \frac{d}{t} = \frac{\lambda}{1/f} = \lambda f$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8\ m/s}{15 \times 10^9} =$$ 3E8 / 15E9 = 0.02 $= 0.02\ m$.

$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi \cdot \frac{\pi}{4}}{(0.02)^2} = \frac{\pi^2}{4 \times 10^{-4}} \approx$$ π² / 4E-4 = 24'674.011

in dB: 10×logANS= 43.92239754 (44 dB).

Exercise 10: A point-to-point link uses a transmit power of 1 Watt, transmit and receive antennas with gains of 20dB and operates at 3 GHz. How much power is received by a receiver 300m away?

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{3 \times 10^9} = 0.1 \text{ m}$$

$$d = 300 \text{ m}$$

$$P_T = 1\text{W}, \quad G_T = G_R = 20\text{dB} = 10^{\frac{20}{10}} = 10^2 = 100$$

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2 =$$

$$= 1 \cdot 100 \cdot 100 \left(\frac{0.1}{4\pi \cdot 300}\right)^2 = \quad 1\text{E}4 \times \left(\frac{.1}{4 \times \pi \times 300}\right)^2 = 7.04\text{E-}06$$

$$\approx 7 \mu\text{W}$$

Exercise 11: Rank each of twisted-pair, co-ax, optical fiber and free space media according to cost of the medium, cost of the interface, media size and immunity to interference.

	cost of media	cost of interface	media size	immunity to interference
TP	L	L	M	worst
co-ax	M H?	M	thickest	medium.
optical fibre	M	M	smallest	best
wireless	L ? (cost of licensing)	H	smallest	worst